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Procedia Environmental Sciences 11 (2011) 637 – 642

Procedia Environmental Sciences

Evaluation of Regional Circular Economy Based on Matter Element Analysis

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Abstract

In order to assess index weighted value scientifically, the fuzzy mathematic and the matter element were introduced into the fuzzy weighted values to set up matter element model based on fuzzy weight. In this way, the model not only holds the merit of classical matter element, but also overcomes its limitations in practice. The model was applied to evaluate the development of circular economy in Beijing, Anhui, Sichuan. It is shown that the quality grade of Beijing is good circle (Ⅰ), Anhui is middle circle (Ⅱ) and Sichuan is basic circle (Ⅲ). The proposed method is proved to be reasonable and reliable, and can be widely used in all kinds of comprehensive evaluation problems.

Keyword: Fuzzy weight; Matter element; circular economy; Evaluation

1. Introduction

Circular Economy is a new, advanced economic model. It follows the principle of 3R, including Reduce, Reuse, Recycle; its purpose is to achieve resource use reduction, product reuse and utilization of waste. In China, Facts proved that circular economic model is in line with the sustainable development concept, which is a great change to traditional economic growth model of the high energy consumption, high emission and low use. It can effectively change the status that the proportion of resource-oriented growth resource is high in the current GDP growth, reflects the harmony between man and nature.

In order to better promote and guide the development of circular economy, we need to clear the grade of economic development in different regional, so as to make development goals and phase development plans. At present, there are many evaluation methods, the most commonly used are: neural network model, analytic hierarchy process, entropy method, factor analysis and other comprehensive evaluation method. These methods have their own characteristics, but in general can be divided into two categories, subjective weight method and objective weight method. Subjective weight method reflects the intention of policy maker, but the evaluation results have a strong subjectivity; Objective weight method avoids the bias

doi:10.1016/j.proenv.2011.12.099

caused by human factors, but sometimes the weight is differ from the actual importance of the various indiators , and results were affected by random errors of sample. Therefore, these two methods have some limitations[1]. Clearly, scientific evaluation method combined a variety of evaluation methods with reason[2]. The author combines fuzzy weight with matter-element analysis, to try to set up matter element model based on fuzzy weight and applied it to the actual evaluation of regional circular economy development, with provide new view to the government decision and allied studies.

2. Matter Element Model Based on Fuzzy Weight

2.1Matter element definition

Suppose that an ordered triple $R=(M,c,v)$,including three elements *M* (the matter), *c* (the matter's property) and *v* (the property's value),is defined as the basic cell, which is a 1 dimensional matter element. Suppose that the matters were characterized with *n* properties ($c_1,c_2,\ldots c_n$) and that the corresponding value of these properties were ($v_1,v_2,\ldots v_n$). Then a matter element is defined as:

$$R=\begin{bmatrix} M & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix}=\begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix}$$

2.2 Classical field and node field

The classical field of the circualr economy is

$$R_j=(M_j,c_i,v_{ji})$$
$$=\begin{bmatrix} M_j & c_1 & v_{j1} \\ & c_2 & v_{j2} \\ & \vdots & \vdots \\ & c_n & v_{jn} \end{bmatrix}=\begin{bmatrix} M_j & c_1 & (a_{j1},b_{j1}) \\ & c_2 & (a_{j2},b_{j2}) \\ & \vdots & \vdots \\ & c_n & (a_{jn},b_{jn}) \end{bmatrix},$$

Where M_j is the circular economic development of grade *j*($j=1,2,\cdots,m$); c_i is the property of M_j $i=1,2,\cdots,n$;and v_{ji} is the classical field of the circular economy, which represents the M_j 's range about c_i .

The node field of the circular economy is

$$R_p=(P,c_i,v_{pi})$$
$$=\begin{bmatrix} P & c_1 & v_{p1} \\ & c_2 & v_{p2} \\ & \vdots & \vdots \\ & c_n & v_{pn} \end{bmatrix}=\begin{bmatrix} P & c_1 & (a_{p1},b_{p1}) \\ & c_2 & (a_{p2},b_{p2}) \\ & \vdots & \vdots \\ & c_n & (a_{pn},b_{pn}) \end{bmatrix},$$

where *P* represents the entire circular economy grades and v_{pi} is the *P*'s range about c_i ..

2.3 Determination of correlation function

The relation between the *i*th property field of circular economy and the *j*th grade can be depicted by a correlation function:

$$K_j(v_i) = \begin{cases} -\dfrac{\rho(v_i, v_{ji})}{|v_{ji}|} \cdots\cdots\cdots\cdots v_i = v_{ji} \\ \dfrac{\rho(v_i, v_{ji})}{\rho(v_i, v_{pi}) - \rho(v_i, v_{ji})} \cdots v_i \notin v_{ji} \end{cases}, \tag{1}$$

where

$$\rho(v_i, v_{ji}) = \left| v_i - \frac{1}{2}(a_{ji} + b_{ji}) \right| - \frac{1}{2}(b_{ji} - a_{ji}) \tag{2}$$

$$\rho(v_i, v_{pi}) = \left| v_i - \frac{1}{2}(a_{pi} + b_{pi}) \right| - \frac{1}{2}(b_{pi} - a_{pi}) \tag{3}$$

2.4 Determination of fuzzy weight

Using fuzzy mathematical method to determine fuzzy weights (A_i) of evaluation factors (c_i):

$$A_i = \frac{\beta_{i,1}}{\delta_{i,1}} + \frac{\beta_{i,2}}{\delta_{i,2}} + \cdots + \frac{\beta_{i,p}}{\delta_{i,p}} + \frac{\beta_{i,0}}{\delta_{i,0}} + \frac{\beta_{i,p+1}}{\delta_{i,p+1}} + \cdots + \frac{\beta_{i,2p}}{\delta_{i,2p}}, \tag{4}$$

where $\delta_{i,0}$ is relative weight, it can be determined according to the method of AHP[3] or the expert survey 9 scale, and $\sum_{i=1}^{n} \delta_{i,0} = 1$; $\beta_{i,k} = (1, 2, \cdots, 2p)$ can be determined according to the actual situation, and often selected 0.5,0.6,0.7,0.8 or 0.9; $\delta_{i,k} = (1, 2, \cdots, 2p)$ can be determined according to the $\delta_{i,0}$.

Fuzzy weight embraces essentially weight range by this method. This method not only inherits the traditional matter element method, but also considers sufficiently the uncertainty of the weight[4,5].

2.5 Determination of correlation degree

One can calculate $K_j(M)$ of *M* about the *j*th grade by:

$$K_j(M) = \sum_{i=1}^{m} A_i K_j(v_i) \tag{5}$$

2.6 Correlation degree Standardization

One can calculate $\overline{K_j}(M)$ of *M* about the *j*th grade by:

$$\overline{K}_j(M) = \frac{K_j(M) - \min_{j=1} K_j(M)}{\max_{j=1} K_j(M) - \min_{j=1} K_j(M)} \tag{6}$$

2.7 Determination of quality grade

The quality grade of surface water is given by

$$\overline{J} = \frac{\sum_{j=1}^{m} j\overline{K}_j(M)}{\sum_{j=1}^{m} \overline{K}_j(M)} \tag{7}$$

3. Case Study

Economy development level is now extremely imbalance in the east, middle and west region of China. East regions, middle regions and west regions accounted for 61.3%, 21.6% and 17.1% of the GDP In 2006, respectively. From the degree of industrialization point view, the eastern region passes from the industrialization to the post industrial society, the degree of industrialization is 70%; the middle and west regions are now in the semi-industrialized society, the degree of industrialization achieved less than 50%[6].In this paper, authors apply the fuzzy weight matter element method to evaluation the development of regional circular economy. Date from *'China Statistical Yearbook'* (2007).

3.1 Index system

At present, scholars made a great of useful researches on building circular economy indexes. The index system is mainly reflected 3 aspects[7-9] as below: economic, environmental, social, weakening the causal relationship between the circular economic internal components, there is no radically different to compare with indexes of sustainable development, but also is not reflect the characteristics and the nature of circular economy. Taking evaluation index system of circular economy(National Development and Reform Commission[2007]No.1815)as the base, '3R' as the principle, considering the availability of data, authors establish index system of circular economy(see Table Ⅰ).

3.2 Standards for index classification grade

Authors referred to HUANG He-ping's grade standards[10] about circular economy indexes, combined with index grade standards of eco-province construction, to arrive at a sensible index grade standard. According to the grade standards, grade Ⅰ,grade Ⅱ, gradeⅢ, gradeⅣ and grade Ⅴ are classified, respectively, corresponding to good circle, Medium circle, common circle, little circle and no circle (see Table 1).

Table 1The regional circular economy index system and quality grade

Target layer	Rule layer	Index layer	Quality grade				
			Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Compre-hensive index of circular economy	Reduce	Energy consumption //tce / 104yuan	0-0.4	0.4-0.8	0.8-1.2	1.2-1.6	1.6-2.0
		water consumption//m3/104yuan	50-100	100-150	150-200	200-250	250-300
		Energy Productivity//104yuan /t	3.0-3.5	2.5-3.0	2.0-2.5	1.5-2.0	1.0-1.5
		Wastewater emission//t/104yuan	10-20	20-30	30-40	40-50	50-60
		Waste gas emission//t/104yuan	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5
		Solid Waste emission//t/104yuan	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0
	Recycle	reuse rate of industrial water/%	90-100	75-90	60-75	45-60	30-45
		comprehensive utilization rate of straw/%	95-100	90-95	85-90	80-85	75-80
		comprehensive utilization rate of industrial solid waste/%	95-100	90-95	85-90	80-85	75-80
	Reuse	innocent treatment rate of urban garbage/%	80-100	60-80	40-60	20-40	0-20

4. Evaluation and Results

Firstly, according to Table 1, we can get the classical field of circular economy. And based on this conclusion, we can get the node fields. Secondly, in accordance with formula (4) calculate the fuzzy weights of the indexes, using formula (1), (2), (3), (5) calculated correlation degree of the index quality grade, then puts the value of correlation degree into formula(6) to obtain the value of standardized treatment. Finally, puts the value of standardized treatment into formula (7) to obtain the quality grade.The results of calculation are given in Table2.

Table2.Evaluation results of regional circular economy

region	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	grade
Beijing	0.720 5	-0.372 9	-0.553 1	-0.737 3	-0.496 6	1.754 6
Anhui	-0.584 9	-0.395 2	-0.671 2	-0.812 5	-2.477 0	2.435 6
Sichuan	-3.023 2	-0.522 0	-0.553 5	-0.885 3	-2.369 2	3.121 7

From Table 2, we can show that the development level of circular economy is different in different regions.

1) Quality grade of Beijing is Ⅰ. The Concluded in *China's Sustainable Development Strategy Report*(Chinese Academy of Sciences for Sustainable Development Research Group) shows that: the ability for sustainable development was enhanced in Beijing, now Beijing is numbered among the best regional of economic development in China, which is coordinated with this paper's. Additionally, from the study on circular economy in Beijing, Hao Li[11] has reached a similar conclusion.

2) Quality grade of Anhui province is Ⅱ. The Anhui Provincial Government issued *Notice about Further Strengthening Energy Saving Work of Anhui Province*, encouraged enterprise to save energy and reduce consumption, enhanced the rates of resource utilization efficiency and further put forward the economic development goals, tasks and measures. By2004,its GDP reached 6148.7 billion yuan and Fiscal revenue reached 81.65 billion yuan. At the same time, there are more than 6523 large-scale industrial enterprises in this province, an increase of 13.6% percentage points year-on-year. The ability for sustainable development was enhanced in Anhui province.

3) Quality grade of Sichuan province is Ⅲ. The proportion of Industry is higher in the Industrial structure,GDP growth follows a great deal of resource consumption. But meanwhile, we should know that Sichuan Province is in the acceleration development stage of industrialization and urbanization. Highly energy consuming mode of economic development will be improved.

The evaluation results based on fuzzy weight matter element reflects the difference among east, middle and west region of China, which coincides with the actual situation [12,13].This method inherits the ideas and advantages of traditional matter element method, in the meanwhile, it overcomes the uncertainty of weight of the traditional matter element method, which has obvious rationality.

5. Conclusions

Authors join fuzzy weight and matter element to set up matter element model based on fuzzy weight. This method not only inherits the traditional matter element method, such as the conceptual clarity, strong logicality, high resolution of evaluation result, etc, but also considers sufficiently the uncertainty of the weight. The results of case study are consistent with the actual situation. The proposed method is proved to be reasonable and reliable, and can be widely used in all kinds of comprehensive evaluation problems.

Acknowledgment

This work was supported by the Education Department of Sichuan, China (No.10ZB020)

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